3. Flight Operations Segment Overview

The EOS Operations Center (EOC) performs mission planning, command and control of the U.S. EOS spacecraft and the U.S. EOS instruments, and coordinates mission operations for other non-U.S. EOS instruments on-board the U.S. spacecraft. The EOC operations support the EOS mission life cycle, which includes pre-launch, launch, and on-orbit operations that occur in parallel with operator simulations training as well as interface tests, system tests, and end-to-end tests; supports concurrent operations with maintenance, system upgrades, and sustaining engineering activities; and supports command, control, and analysis of multiple spacecraft and their instruments simultaneously.

The EOC is located at the Goddard Space Flight Center in Greenbelt, Maryland, and is operated by the Flight Operations Team (FOT). The Flight Operations Team is responsible for maintaining spacecraft and instrument health and safety, monitoring spacecraft performance, performing spacecraft engineering analysis, performing high-level monitoring of the mission performance of the instruments, and providing periodic reports to document the operations of the spacecraft and instruments.

U.S. EOS instrument operations are distributed through the use of Instrument Support Terminal (IST) toolkits, which are deployed at instrument Principal Investigator/Team Leader (PI/TL) facilities. IST toolkits enable PI/TLs to remotely participate in the planning, scheduling, monitoring, and analysis of their instruments in conjunction with the FOT at the EOC.

Currently, all identified U.S. EOS instruments are managed at the EOC with access provided to the PI/TL via the IST. If, in the future, a complex instrument requiring a dedicated facility for control and monitor functions is identified, an Instrument Control Center (ICC) may be established.

Section Organization

Flight operations concepts are included in this section of the FOS Requirements Specification document. In particular:

- Section 3 provides an overview of flight operations, introducing the two operational entities associated with flight operations -- i.e., the EOC and the IST. In addition, the primary flight operations activities are summarized and introduced.
- Section 3.1 provides a context description of the flight operations activities in relation to the primary external interfaces.
- Section 3.2 discusses the flight operations concepts based on operational scenarios. The flight operations scenarios are partitioned into three activity phases -- i.e., scheduling, real-time telemetry and command operations, and analysis. Operational scenarios for each of these three activity phases are presented.

Flight Operations Activities

Eight subsystems have been defined to support flight operations. These subsystems are Planning and Scheduling, Command Management, Command, Telemetry, Resource Management, Real-Time Contact Management (RCM) Analysis, Data Management, and User Interface. Individually these subsystems perform specific, unique functions; collectively, they provide a set of interrelated services for the Flight Operations Team (FOT) and the IST user community.

Following are descriptions of the eight flight operations subsystems as organized to support the flight operations activity phases:

Scheduling Activity Phase:

Planning and Scheduling: The Planning and Scheduling subsystem integrates plans and schedules for spacecraft, instruments, and ground operations. It also coordinates multi-instrument observations, if any. The Planning and Scheduling subsystem utilizes a common set of capabilities to perform "what-if" analyses and to visualize plans and schedules.

The PI/TLs can actively participate in the EOS mission planning process through the planning and scheduling tools in the IST toolkit. Included in the toolkit are global visibility into the mission timeline and the set of scheduling products generated at the EOC.

Command Management: The Command Management subsystem manages the pre-planned command data for the spacecraft and instruments. Based on inputs received from the Planning and Scheduling subsystem, the Command Management subsystem collects and validates the commands, software memory loads, table loads, and instrument memory loads necessary to implement the instrument and spacecraft scheduled activities.

Real-Time Activity Phase:

Command: The Command subsystem is responsible for transmitting command data (i.e., real-time commands or command loads) to EDOS for uplink to the spacecraft during each real-time contact. Command data can be received in real-time by the operational staff or as preplanned command groups generated by the Command Management subsystem. The Command subsystem is also responsible for verifying command execution on-board the spacecraft.

Telemetry: The Telemetry subsystem receives and processes housekeeping telemetry (in CCSDS packets) from EDOS. After the packet decommutation, the telemetry data is checked against boundary limits and converted to engineering units.

Analysis Activity Phase:

Analysis: The Analysis subsystem is responsible for managing the on-board systems and for the overall mission monitoring. Its functions include performance analysis and trend analysis. It also cooperates with the Telemetry subsystem to support fault detection and isolation.

Support Services:

Resource Management: The Resource Management subsystem provides the capability to manage and monitor the configuration of the EOC. This includes configuring the EOC resources for multi-mission support; facilitating operational failure recovery during real-time contacts; and managing the real-time interface with the NCC.

Data Management: The Data Management subsystem is responsible for maintaining and updating the Project Data Base (PDB) and the EOC history log.

User Interface: The User Interface subsystem provides character-based and graphical display interfaces for EOC operators and PI/TLs (using the IST toolkit) interacting with all of the aforementioned flight operations services.

3.1 Flight Operations Context Description

The context diagram in Figure 3.1-1 shows the relationship between the EOC and its external interfaces. Figure 3.1-2 shows the relationship between the IST toolkit and its interface with the SCF for importing and exporting microprocessor memory load and dump data, respectively. Table 3.1-1 summarizes the EOC and IST toolkit external interfaces, and includes the nominal frequency for each interface item in addition to providing the source and destination of the interface and a description of the data.

There are several notes pertaining to the EOC external interfaces:

- The EOC interfaces with the International Partner Instrument Control Center (IP-ICC) could be applied to any ICC that is external to the EOC at GSFC, even one within the U.S.
- The IST toolkit interface to the Science Computing Facility (SCF) is included in this section. The SCF is the facility that provides the hardware where the IST software toolkit resides. However, while every U.S. EOS instrument has an IST software toolkit, not every U.S. EOS instrument has an SCF (e.g., MOPITT instrument on the AM-1 spacecraft). For simplification reasons, the reference to SCF in this document also includes any PI/TL facility where the IST software toolkit resides. The SCF, in the context of being an interface to the IST toolkit, pertains to the PI/TLs software that imports/exports data from flight operations via the IST toolkit.
- The term archive is used in several contexts in this document. The SDPS provides the long-term storage of flight operations archive data, while the EOC provides the short-term storage of flight operations archive data (nominally data seven days old or less).
- **CSMS Interface:** The CSMS Management Subsystem (MSS) (also known as the SMC) sends the Long-Term Instrument Plans and the Long-Term Science Plans to the EOC. These sets of plans are produced/updated by the Investigator Working Group (IWG) every six months and cover a period of up to approximately five years. The EOC sends management and operational status information to the CSMS.

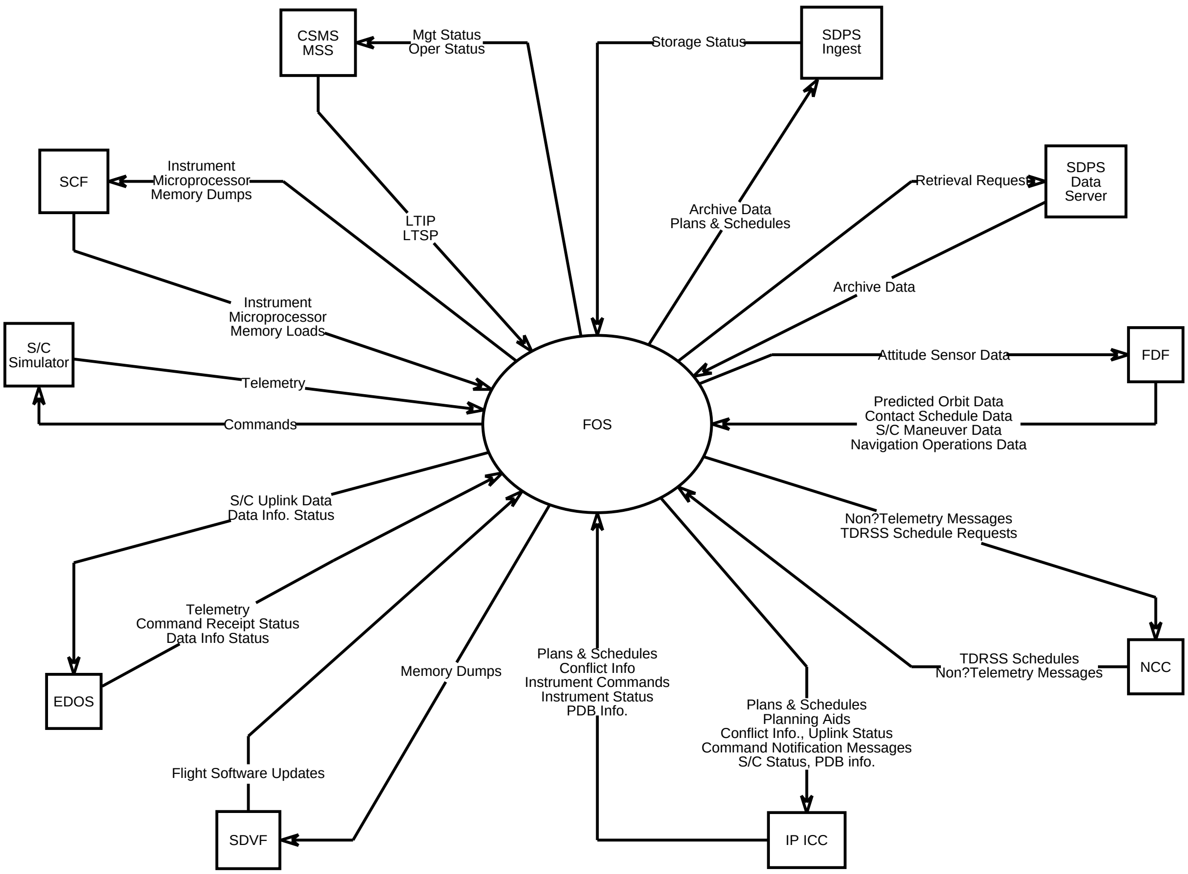

Figure 3.1-1. EOC Interface Diagram

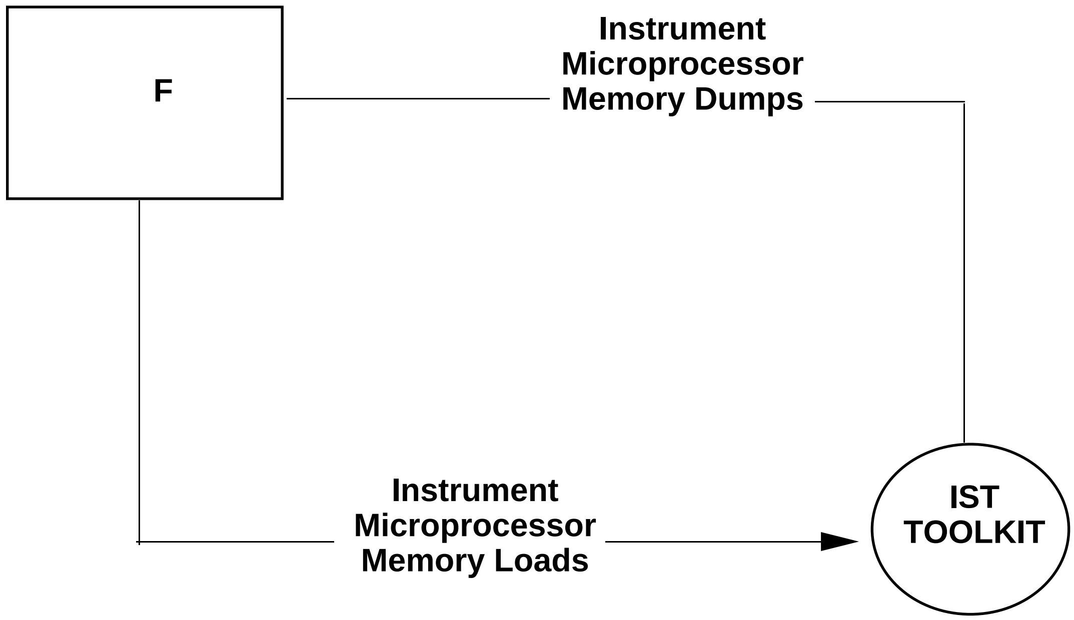

Figure 3.1-2. IST Toolkit External Interface Diagram

- **SDPS Interfaces:** The SDPS provides long-term archiving services for the flight operations data. The data sent to the SDPS includes the spacecraft and instrument housekeeping telemetry, engineering telemetry, event history data, etc. (Note: this data can be retrieved from the SDPS at a later time.)
- Additionally, the EOC sends mission plans and schedules to the SDPS.
- The SDPS also sends engineering data to the EOC, and processes requests for flight operations data that had been previously stored in the long-term archive.
- **FDF Interface:** The Flight Dynamics Facility (FDF) sends predicted orbit data to the EOC for scheduling purposes. The FDF also sends contact scheduling data such as User Antenna View (UAV) data and TDRSS and ground station viewing times to the EOC. The FDF develops plans for spacecraft maneuvers in conjunction with the EOC and sends the spacecraft maneuver parameters to the EOC. The Flight Operations Team (FOT) schedules and implement these plans. The FDF also sends parameters needed for spacecraft on-board table generation to the EOC. FDF parameters consist of navigational operational parameters and spacecraft maneuver parameters.

  The EOC provides attitude sensor data to the FDF for analysis. This data is a subset of the spacecraft housekeeping telemetry nominally captured by the EOC during a real-time contact. In addition, back orbit telemetry subsets may also be sent to the FDF from the EOC.
- **NCC Interface:** The EOC submits TDRSS schedule requests and other non-telemetry messages (e.g., link reconfiguration requests) to the Network Control Center (NCC) . In response, the NCC sends TDRSS schedules notifying the EOC of the status of its request and non-telemetry messages (e.g., TDRSS link status messages, performance data). In the

event TDRSS is unavailable, the EOC also interfaces with the NCC to schedule ground station contacts with the contingency networks (i.e., Deep Space Network, Ground Network, or Wallops Orbital Tracking Station).

- **IP-ICC Interface:** International Partners (IPs) may provide their own Instrument Control Center (ICC) for their instrument on-board an EOS spacecraft. For example, Japan will provide an IP-ICC for the ASTER instrument on-board the AM-1 spacecraft. The IP-ICC provides instrument plans and schedules to the EOC, and coordinates scheduling conflicts with the EOC when they arise. The EOC sends planning aids, integrated mission plans and schedules to the IP-ICC for analysis to refine instrument scheduling, and also receives scheduling conflict information from the EOC.

  An IP-ICC can send instrument commands to the spacecraft via the EOC. The EOC validates each command sent from an IP-ICC and builds the command bit pattern. The EOC sends the command to the spacecraft via the EDOS interface. The EOC reports on the uplink status to the IP-ICC. In addition, the EOC can send commands to the spacecraft on behalf of the instrument (e.g., to safe the instrument). The EOC notifies the IP-ICC with a command notification message in this situation.

  An IP-ICC can send instrument data base update requests to the EOC. After the data base update request has been approved, or whenever a new project data base has been established in the EOC, the updated project data base will be sent to the IP-ICC.

  Periodically, the EOC sends mission status information to the IP-ICC, and the IP-ICC sends instrument status to the EOC.

Note: throughout the remainder of this document, reference to the IP-ICC also includes any external ICC.

- **SDVF Interface:** The Software Development and Validation Facility (SDVF) sends flight software loads to the EOC. These loads are scheduled by the EOC for subsequent uplink to the spacecraft. The EOC may send memory dumps to the SDVF.
- **EDOS Interface:** EDOS provides the EOCs interface with the SN, DSN, GN, and WOTS for spacecraft commanding and telemetry operations. The EOC sends spacecraft uplink data, including spacecraft and instrument commands and command loads, to the spacecraft via the EDOS interface. EDOS, in turn, provides the EOC with spacecraft command receipt status.

  EDOS sends spacecraft and instrument housekeeping telemetry in real-time from the spacecraft to the EOC. This data will be used by the FOT to monitor the health and safety of the spacecraft and instruments during real-time contacts, and to perform command verification.

  EDOS also sends back-orbit housekeeping telemetry from the spacecraft to the EOC. This data will be sent via the rate-buffered service that EDOS provides after a contact has been completed.

  Data interface status messages are also sent between the EOC and EDOS.

- **Spacecraft Simulator Interface:** The EOC sends spacecraft and instrument commands to the Spacecraft Simulator. The Spacecraft Simulator sends simulated spacecraft telemetry to the EOC. This interface is provided for the purpose of flight operations training and development, and validation of operational procedures.

- **SCF Interface:** Microprocessor memory loads for instruments can be submitted to the EOC via the IST toolkit from the SCF. These microprocessor memory loads are scheduled by the EOC for subsequent uplink to the spacecraft. The EOC sends microprocessor memory dumps to the SCF via the IST toolkit. The SCF also has a general interface with the EOC via the IST toolkit to import and export other data (e.g., telemetry data files).

Table 3.1-1. Flight Operations External Interfaces (1 of 2)

Source	Destination	Data Description	Frequency
CSMS	EOC	LTIP	every 6 months
CSMS	EOC	LTSP	every 6 months
EOC	CSMS	Management status	as required
EOC	CSMS	Operational status	as required
EOC	SDPS	Archive data	daily for long-term storage
EOC	SDPS	Plans and Schedules	daily
SDPS	EOC	Storage status	for each long-term storage request
EOC	SDPS	Retrieval request for long term flight operations data in long-term archive	as requested primarily for analysis
SDPS	EOC	Engineering product	as requested (very infrequent)
FDF	EOC	Predicted orbit data	daily/weekly
FDF	EOC	Contact schedule data	daily/weekly
FDF	EOC	Spacecraft maneuver data	nominally every 45 days
FDF	EOC	Navigation operations data	daily
EOC	FDF	Attitude sensor data	each spacecraft contact
NCC	EOC	TDRSS schedules	weekly/ daily updates
NCC	EOC	Non-telemetry messages	each TDRSS contact
EOC	NCC	TDRSS schedule requests	weekly/ daily updates
EOC	NCC	Non-telemetry messages	each TDRSS contact
IP-ICC	EOC	Plans and schedules	daily
IP-ICC	EOC	Conflict info	nominally daily

Table 3.1-1. Flight Operations External Interfaces (2 of 2)

Source	Destination	Data Description	Frequency
IP-ICC	EOC	Instrument commands	infrequent; based on mission requirement
IP-ICC	EOC	Instrument status	weekly
IP-ICC	EOC	Data base information	nominally every 3 months
EOC	IP-ICC	Plans and schedules	daily
EOC	IP-ICC	Planning aids	daily/weekly
EOC	IP-ICC	Conflict info	as applicable
EOC	IP-ICC	Uplink status	each IP-ICC command sequence
EOC	IP-ICC	Command notification messages	each unplanned IP-ICC command issued from EOC
EOC	IP-ICC	Spacecraft status	weekly
EOC	IP-ICC	Data base information	nominally every 3 months
SDVF	EOC	Flight software updates	infrequent 4/year
EOC	SDVF	Memory dumps	as requested 4/year
EDOS	EOC	Telemetry	each spacecraft contact
EDOS	EOC	Command receipt status	each command sequence
EDOS	EOC	Data information status	periodically during each spacecraft contact
EOC	EDOS	Spacecraft uplink data	each command sequence
EOC	EDOS	Data information status	each spacecraft contact
Spacecraft Simulator	EOC	Telemetry	as required; nominally infrequent
EOC	Spacecraft Simulator	Commands	as required; nominally infrequent
SCF	IST Toolkit	Instrument Microprocessor Memory Load	as required; nominally infrequent
IST Toolkit	SCF	Instrument Microprocessor Memory Dump	as required; nominally infrequent

3.2 Flight Operations Scenarios

The operational scenarios delineated in this subsection provide a representative discussion of the flight operational concepts and functional requirements. The operational scenarios illustrate how the flight operations services are integrated to fulfill the disparate requirements of the flight operations staff and the PIs/TLs. A detailed, comprehensive discussion of flight operational concepts is included in Appendix A, of the ECS Operations Concept Document for the ECS Project.

Planning, scheduling, commanding, and telemetry monitoring of the EOS spacecraft will be performed on a spacecraft-by-spacecraft basis by the Flight Operations Team (FOT). Parallel but separate configurations (e.g., data bases, schedules, commands, and archive files) will be maintained for each EOS spacecraft. This approach facilitates the concurrent support of multiple spacecraft with different science goals and overlapping TDRSS contacts.

The separate configuration approach also is applied to the replacement of an EOS spacecraft within a series. For example, separate configurations are maintained for the AM-1 and AM-2 spacecraft. Similarly, this approach is applied to enable the FOT to perform on-going support of spacecraft in-orbit and spacecraft in the operations testing phase. Flight Operations can be configured so that support for multiple spacecraft in-orbit is physically separated from the operations associated with spacecraft in the operations testing phase. This capability provides an additional level of control and security to flight operations.

The block diagram in Figure 3.2-1 outlines the different groups of personnel involved in Flight Operations, their applicable functional area(s), and their external interfaces. For instance, the Spacecraft Evaluator monitors the telemetry housekeeping data, identifies anomalies, and issues problem reports, as applicable.

The Command Activity Controller position executes the ground script that sends commands and command loads to the spacecraft. Constraints are checked to ensure that only the single authenticated Command Activity Controller position has authority to send commands per spacecraft.

The health and safety of multiple instruments can be monitored by a single Instrument Evaluator. This operational approach can be efficiently performed due to the nature of the instruments, which are primarily non-complex.

Figure 3.2-1, as well as the operational scenarios described in the remainder of this section, are partitioned into four primary areas: planning and scheduling, command management, real-time command and telemetry, and spacecraft and instrument analysis.

The Planning and Scheduling services coordinate and integrate instrument and spacecraft bus command and control requests. It requires the cooperative effort between the FOT planning and scheduling staff, the instrument planning and scheduling staff, and the PI/TL representatives. Instrument (PI/TL) requests are submitted to the EOC Schedulers in the form of activity requests. The EOC Schedulers constraint-check the activity requests, assign priorities, and develop a schedule of activities for the instrument. The EOC Schedulers schedule the spacecraft bus subsystems to efficiently use spacecraft resources and execute orbital maneuvers. In addition, the EOC Schedulers integrate the instrument and spacecraft subsystem activities (i.e., the detailed activity schedule) into an overall schedule. The final schedules are available to the PI/TLs via their

IST. The PI/TLs ensure that their instruments are configured to collect the desired science data and ensure the quality of their instruments.

The Command Management services use the detailed activity schedule previously developed to generate the ground scripts that are used during a real-time contact with the spacecraft to send commands and command loads (including SCC loads and microprocessor memory loads) to the spacecraft. The EOC Scheduler integrates this command data with the spacecraft subsystem commands and command loads into a ground script. In addition to the command data, the ground script includes the directives required to configure the EOC to support the pre-contact, contact, and post-contact operations (e.g., load the correct data base).

The Command and Telemetry services provide the Command Activity Controllers the ability to execute the ground script generated for that day's activities by the EOC Schedulers. The Command Activity Controllers verify that the stored commands are successfully loaded on-board the spacecraft for subsequent execution, as well as the loading and execution of real-time commands. The Spacecraft Evaluators monitor the telemetry housekeeping data downlinked from the spacecraft. In parallel, the instrument housekeeping and engineering telemetry are monitored by the Instrument Evaluators at the EOC and/or PI/TL at the IST. An operational concept highlighted in this area is the concurrent real-time operations of commanding and monitoring multiple spacecraft.

While Spacecraft Evaluators focus on identifying and resolving spacecraft and/or instrument anomalies during real-time, FOT S/C Evolutions (FSE) and Off-Line Engineers review telemetry trend data to identify and resolve spacecraft degradation and resource problems. The Spacecraft Analysis services provide the Spacecraft Engineers with the tools to identify potential and actual problems so that a pre-emptive or corrective action plan can be implemented. For instance, a battery monitoring tool may indicate a battery degradation problem. The Spacecraft Engineer would modify operational procedures vis-a-vis the battery. This corrective action would modify the operational environment of the battery.

3.2.1 Scheduling Scenario

The objective of the scheduling activity phase is to produce an integrated schedule of activities for the instruments and spacecraft subsystems. The process has a distributed architecture, allowing for input from the external science community. In addition, the distributed design permits a separated network of principal investigators (PIs) and/or team leaders (TLs) to have direct input into the planning and scheduling of their instruments. As shown in Figure 3.2.1-1, scheduling has four primary components: long-term planning, initial scheduling, final scheduling, and command load generation.

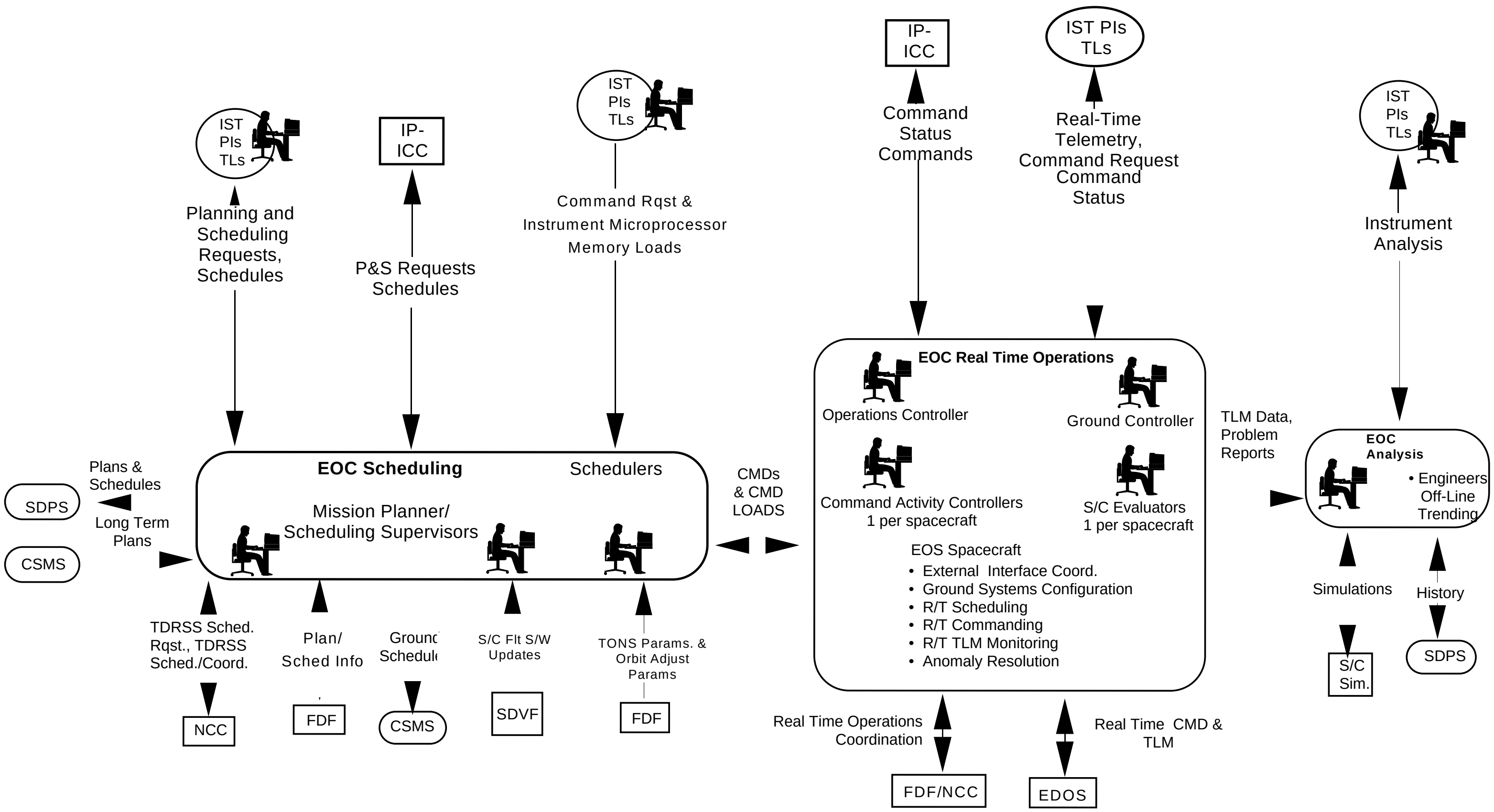

Figure 3.2-1. Flight Operations' System Level Concepts

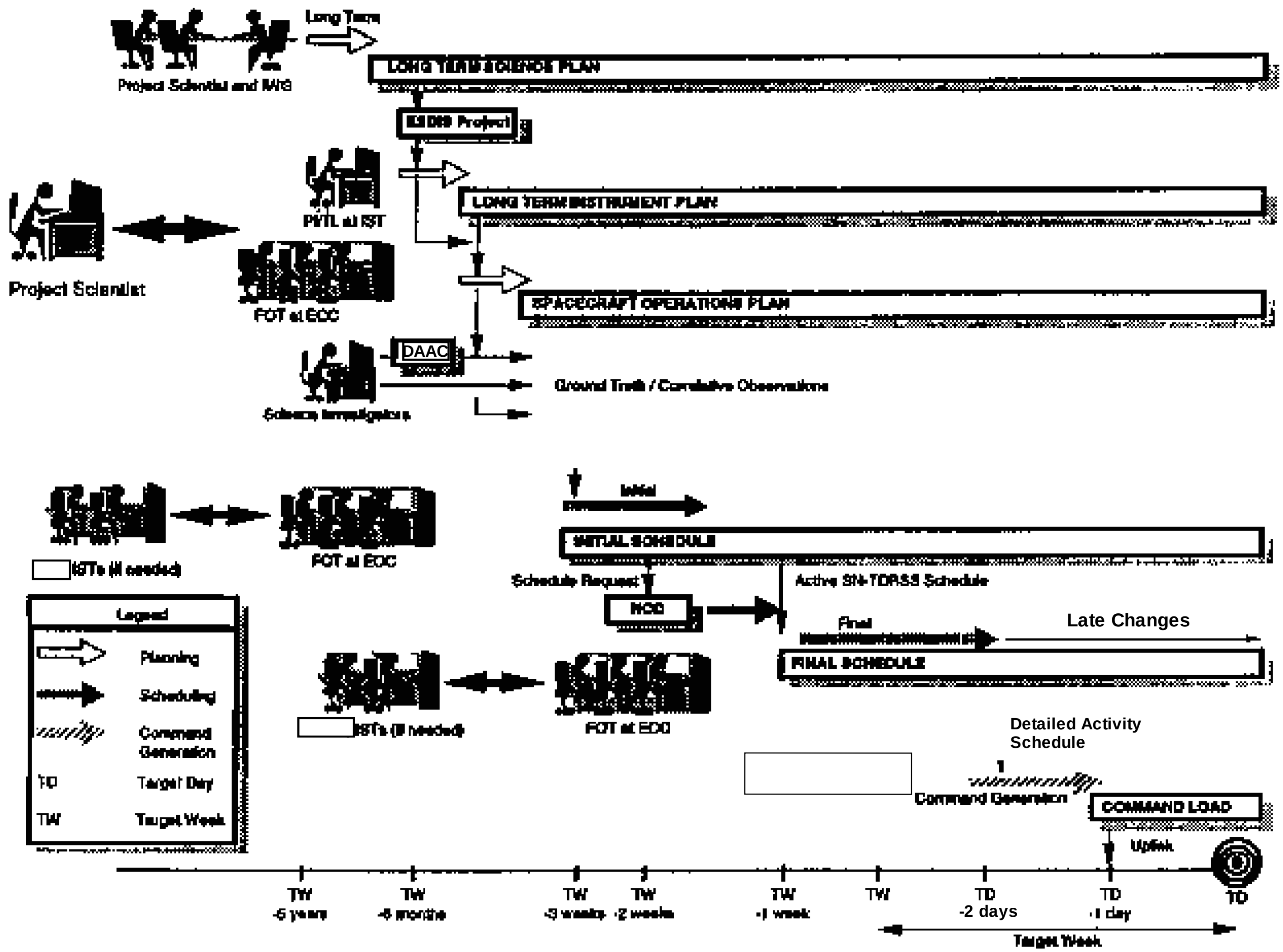

Figure 3.2.1-1. Scheduling Process

3.2.1.1 Long-Term Planning

The project scientist is involved in every aspect of long-term planning, which involves the development of plans related to science objectives, instrument operations and spacecraft operations. Approximately every six months, scientists and other technical members of the IWG meet with the project scientist to develop a Long Term Science Plan (LTSP) that defines the primary science objectives of the EOS spacecraft and instruments for the next five years. Using input from the LTSP, the PI/TL for an instrument works with the project scientist to develop a Long Term Instrument Plan (LTIP). An LTIP is also a five year plan that includes instrument-specific details on collections, maintenance and calibrations. The LTSP and LTIPs establish the framework for the collections performed by the EOS spacecraft. The EOC receives the LTSP and LTIPs via the System Monitoring and Coordination (SMC).

The final long-term spacecraft plan is developed with input from the Off-Line Engineers of the Flight Operations Team (FOT). In conjunction with the project scientist, a long-term spacecraft operations plan is developed by the EOC scheduler using the LTSP and LTIPs. The long-term spacecraft operations plan outlines anticipated subsystem operations and maintenance, along with forecasted orbit maneuvers from the Flight Dynamics Facility (FDF). The FDF also supplies the EOC with propagated spacecraft ephemeris needed for planning and scheduling.

With all three long-term plans developed, the EOC/ISTs can produce Baseline Activity Profiles (BAP) for their non-complex instruments. A BAP is a schedule of activities corresponding to normal instrument operations. Simple instruments rarely deviate from their BAP, and their scheduling process is often complete at this stage. However, the more complex an instrument, the more frequent are the deviations that occur. In addition, true complex instruments do not have BAPs because their scheduled activities significantly vary due to criteria. The scheduling of deviations to BAPs, along with the scheduling of more complex instruments, is dependent upon available resources, with the most important for the AM-1 spacecraft being TDRSS contact times. The objective of initial scheduling is to allocate these communication times through the NCC.

3.2.1.2 Initial Scheduling

For some U.S. EOS instruments, on a pre-negotiated basis, the PI/TL of the IST predicts their instruments' resource requirements. For the remaining EOS instruments, the instrument scheduler at the EOC predicts the instruments' resource requirements. IP-ICCs are also involved in initial scheduling by providing the EOC with the necessary resource information. With this information, the EOC can negotiate with the NCC for TDRSS contact times.

U.S. EOS instruments have a BAP developed during the long-term planning process. The PI/TL at the IST determines if the BAP for the target week is acceptable. Being deemed adequate, all scheduling for the target week would be complete, and no further actions would be taken. However, a decision to modify the BAP may arise from recent collection requirements, instrument support activities and spacecraft activities that impact the instrument. The EOC Scheduler in coordination with the PI/TL at the IST develops deviations to the BAP (based on a pre-negotiated basis). The EOC is responsible for constraint checking any resource deviations and getting PI/TL approval for the resource deviations prior to submitting the deviation list to the EOC Scheduler for all instruments assigned to it. Similarly, the PI/TL at the IST is responsible for constraint checking any resource deviations prior to submitting the deviation list to the EOC Scheduler if primary planning and scheduling responsibility has been assigned to the PI/TL. The PI/TL participates in the planning and scheduling process through their IST system. Three weeks before the target week, the EOC Scheduler merges the deviation lists with their corresponding BAPs to generate the instrument resource profiles, representing the instruments' resource needs over the target week.

IP-ICCs have the capability to interface with the EOC during all phases of schedule development. During initial scheduling, the IP-ICC develops an instrument resource profile that details instrument resource needs. The EOC Scheduler receives this profile three weeks before the start of the target week.

Like the instruments, spacecraft subsystems also require certain resources during operation. To account for their resource needs, the EOC Scheduler at the EOC performs the necessary analyses and generates the spacecraft subsystem resource profile based upon inputs from the Off-line Engineers.

With the resource profiles for the instruments and spacecraft subsystems, the EOC Scheduler integrates them together to determine the overall spacecraft and instrument resource requirements for the target week. Based on these resource needs, the EOC Scheduler formulates the desired TDRSS contact times and submits them to the NCC. If the requested times are not allocated by the NCC, the EOC may negotiate with the NCC for the best available TDRSS contact periods. Negotiations can take place until one week before the target week, when the NCC provides the active TDRSS schedule to the EOC.

Approximately one week before the target week, the EOC Scheduler incorporates the NCC's TDRSS times into a preliminary resource schedule and sends it to the ISTs and the IP-ICC. If modifications were made to the original instrument resource profiles, notification of the changes, along with a reason, is also being sent to the appropriate IST. With the TDRSS contact times, the PIs/TLs and EOC Scheduler has the necessary information to begin final scheduling.

3.2.1.3 Final Scheduling

The final scheduling phase begins one week prior to the target week. The EOC Scheduler in coordination with the PI/TL at the IST, or the PI/TL at the IST, develops a list of activities required for the instrument based on maintenance activities, calibrations, and/or spacecraft activities. For U.S. EOS instruments, an activity deviation list is created. The EOC Scheduler is responsible for constraint checking the activities and getting PI/TL approval prior to forwarding the activity deviation list to the EOC Scheduler, for all instruments assigned to it. Similarly, the PI/TL at the IST is responsible for constraint checking the activities prior to forwarding the activity deviation list to the EOC Scheduler, if primary planning and scheduling responsibility has been assigned to the PI/TL. For IP-ICCs, activity lists are created and submitted to the EOC.

The EOC Scheduler integrates all the instrument and spacecraft activities and performs conflict resolution to produce a detailed activity schedule. The EOC Scheduler notifies the EOC Scheduler or the PI/TL at the IST of any activities that were rejected due to conflict. The EOC Scheduler or the PI/TL at the IST decides on resubmitting the rejected activities or rescheduling them on a future target day, if possible. IP-ICC Schedulers are also be notified of scheduling conflicts, allowing activities to be resubmitted if desired.

During the final scheduling process, a certain amount of analysis and coordination may take place to incorporate activities into the detailed activity schedule. Figure 3.2.1-2 presents a functional example of the IST and EOC during final scheduling constraint resolution. The scenario assumes the primary instrument planning and scheduling role has been established at the EOC based upon a pre-negotiated basis.

An example of an IST scheduling request might be a request to place the instrument in a calibration mode over a specified time period. A description of the steps in Figure 3.2.1-2 are shown below. Steps with the same number and "a" or "b" indicate either of these paths could occur at this point.

1. The PI/TL at an IST decides to send a modification to the preliminary resource schedule. Using analysis tools such as a map display, the PI/TL can check for target/region visibility, potential scheduling opportunities and other types of data. The request is sent to the instrument EOC Scheduler for further analysis and incorporation into the instrument schedule. In addition, the PI/TL may include a certain degree of flexibility in the request, such as various collection times.
2. The instrument EOC Scheduler receives the request from the IST. After inspection, the instrument EOC Scheduler may contact the PI/TL for clarification. The instrument EOC Scheduler performs a variety of analyses, including conflict resolution, resource availability and science assessment. Constraint checking is instrument specific, leaving the more detailed inter-instrument and subsystem constraint modeling to the spacecraft EOC Scheduler. However, the instrument EOC Scheduler does have the capability to submit “what-if” schedules for analysis purposes. Based on the available resources and activity conflicts, the instrument EOC Scheduler establishes a schedule priority for the activity.
3. If the instrument EOC Scheduler cannot schedule the request, the IST is notified along with an explanation. At this point, the PI/TL may decide to modify the request for EOC acceptance.

   If the instrument EOC Scheduler accepts the IST’s request, it is included in the instrument activity deviation list.
4. The spacecraft EOC Scheduler integrates the list with those received from the other instruments, including the spacecraft subsystems’ activity lists. This allows the spacecraft EOC Scheduler to analyze overall resource availability and investigate any health and safety constraints that affect the spacecraft or instruments. The resource model at the EOC includes the modeling of inter-instrument constraints (e.g., jitter or electromagnetic interference) and subsystem constraints (e.g., data volume). The spacecraft EOC Scheduler attempts to overcome constraints by using any provided flexibility in the activities. If the spacecraft EOC Scheduler cannot resolve a scheduling conflict, the Project Scientist at the EOC has the final decision.

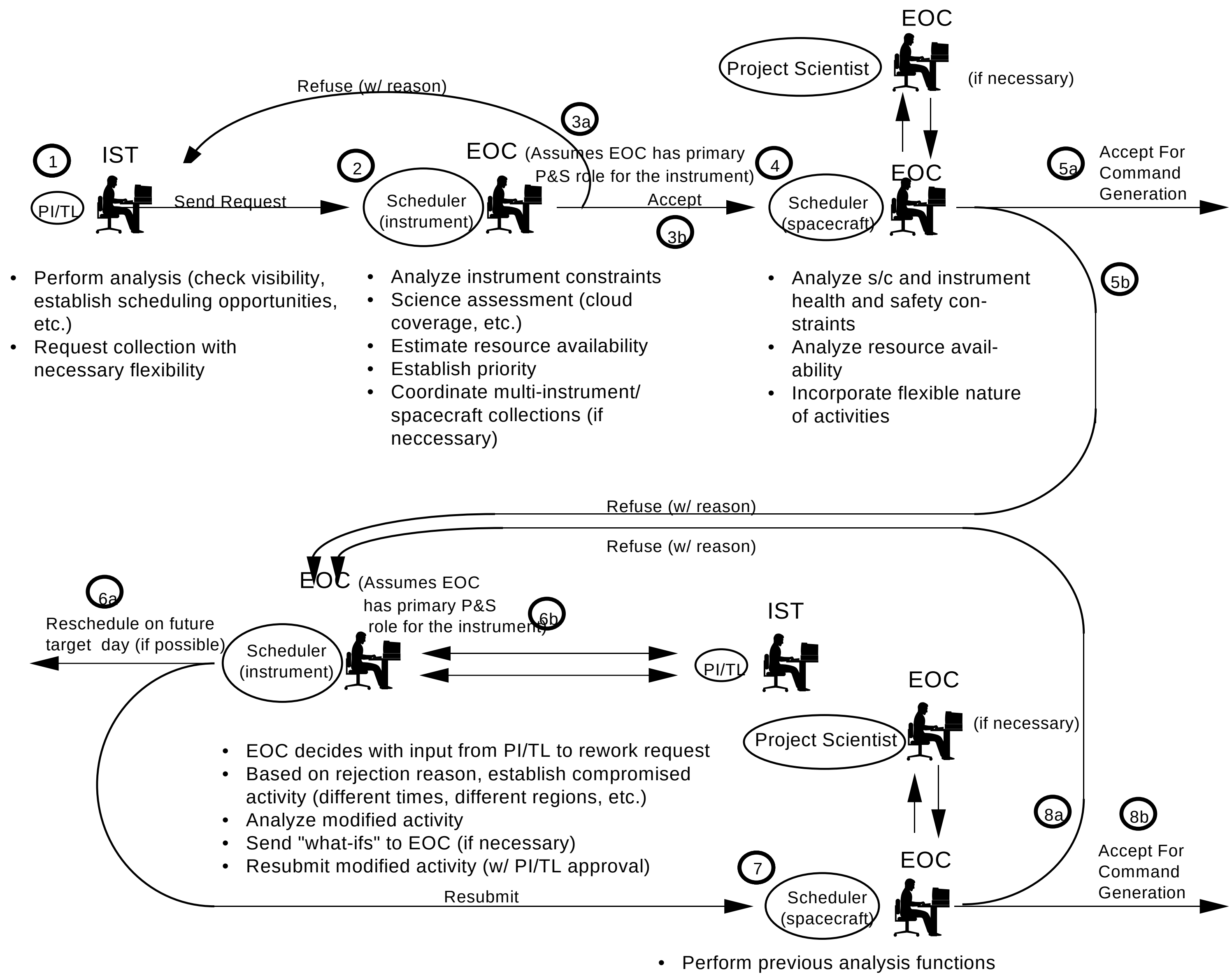

Figure 3.2.1-2. Final Scheduling Constraint Resolution

5. The spacecraft EOC Scheduler accepts the PI/TL's request. The spacecraft EOC Scheduler includes the activity in the detailed activity schedule that will be used for command generation.

   The spacecraft EOC Scheduler discovers a constraint conflict with the PI/TL's request. Therefore, it is not included in the detailed activity schedule, and an explanation for the non-acceptance is sent to the PI/TL and instrument EOC Scheduler.

6. Upon notification of rejection, the instrument EOC Scheduler contacts the PI/TL at the IST, and they decide to reschedule the activity on a later target day, if possible.

   Upon notification of rejection, the instrument EOC Scheduler contacts the PI/TL at the IST, and they decide to rework the activity for the given target day. Based on the reason for rejection, the PI/TL may modify certain details of the request. These may include the desired collection times or the collection areas. Using the modified activity, the instrument EOC Scheduler once again performs the necessary analyses to check instrument constraints and resources. At this stage, the instrument EOC Scheduler may desire to check the detailed inter-instrument and subsystem constraints. To accomplish this, “what-if” analysis is performed for checking the overall impact of the modified activity. Once the instrument EOC Scheduler develops an acceptable compromise, the PI/TL is contacted for approval, and it is resubmitted to the spacecraft EOC Scheduler in the instrument activity deviation list.

7. The spacecraft EOC Scheduler receives the instrument activity deviation list that includes the PI/TL’s modified activity. As before, the spacecraft EOC Scheduler analyzes the overall resources and constraints, with assistance from the Project Scientist, if necessary.

8. This time, the spacecraft EOC Scheduler discovers a different constraint conflict associated with the PI/TL's request. Therefore, it is not included in the detailed activity schedule and an explanation for the non-acceptance is sent to the PI/TL and instrument EOC Scheduler. If there is still allowable time, the instrument EOC Scheduler and PI/TL may once again decide to rework the request for acceptance (step 6b). The constraint resolution procedure will occasionally require multiple iterations.

9. The spacecraft EOC Scheduler accepts the PI/TL's modified request. The spacecraft EOC Scheduler includes the activity in the detailed activity schedule that will be used for command generation.

Approximately two days before the target day, the EOC sends the detailed activity schedule to the ISTs and IP-ICCs. Late changes (including Targets of Opportunity (TOOs) from a complex instrument IP-ICC) are still being accepted up to 24 hours before an observation. Between 24 hours and 6 hours of an observation, a late change may be accepted for possible implementation if it does not affect the previously scheduled activities. Within 6 hours before the observation to 1 hour before the last TDRSS contact prior to the observation, the late change is accepted if it requires only real-time commands. The Mission Operations Manager assigns the responsibility of verifying that real-time command changes have no effect on the spacecraft and instrument health and safety to a Flight Operations Director. For historical purposes, all activity changes are described in the detailed activity history log.

3.2.1.4 Command Load Generation Scenario

The normal procedures for command and control of the EOS spacecraft and instruments are based upon the detailed activity schedule which is generated by the FOS Planning and Scheduling service. The Command Management service is that portion of the FOS which is responsible for translating activities in the detailed activity schedules into Spacecraft Control Computer (SCC)-stored instrument commands, SCC-stored instrument loads, instrument micro-processor loads, SCC-stored spacecraft commands, SCC-stored spacecraft tables and ground scripts. The combination of these commands and tables, as well as the SCC software updates provided by the spacecraft contractor, are uplinked to the EOS spacecraft during the appropriate TDRSS contact.

NOTE: The ground script consists of time stamped directives for the EOC to process the current day's contact periods. The directives include ground directives and real-time spacecraft commands, spacecraft loads and instrument microprocessor loads.

The following scenario, depicted in Figure 3.2.1-3, describes the role of the EOC and IST Schedulers in nominal operations. Inputs to this scenario include: the detailed activity schedule generated by the Planning and Scheduling service; orbital data provided by the Flight Dynamics Facility (FDF); instrument flight software provided by the PI/TL and spacecraft flight software provided from the SDVF. Outputs from this scenario include a spacecraft load ground script for use in real-time operations.

1. Approximately two days prior to the target day, both the EOC and the PI/TL at the IST receive the detailed activity schedule (including late changes) from the Planning and Scheduling service.
2. For some instruments, on a pre-negotiated basis, the PI/TL at the IST is responsible for the generation and validation of their instrument microprocessor loads and pre-planned real-time instrument commands (note: generation and validation of the instrument flight software loads remain the responsibility of the PI/TL using non-ECS tools). For the remaining instruments, the EOC Scheduler is responsible for the generation and validation of instrument microprocessor loads and pre-planned real-time instrument commands. The generated commands are validated to ensure that they do not violate any operational constraints of the instrument.
3. The pre-planned instrument commands and instrument microprocessor loads are sent to the EOC to be incorporated into the ground script.
4. The FDF provides the EOC with orbit adjustment data and TDRSS Onboard Navigation System (TONS) information.
5. As required for spacecraft operations, the SDVF supplies the EOC with any updates to the spacecraft’s flight software.

   The EOC Scheduler generates spacecraft commands and spacecraft tables based on the detailed activity schedule.
6. Additionally, the EOC Scheduler generates instrument commands and tables for IP-ICC instruments based on the IP-ICC command requests and instrument databases. (This allows the FOS to ensure spacecraft health and safety.)

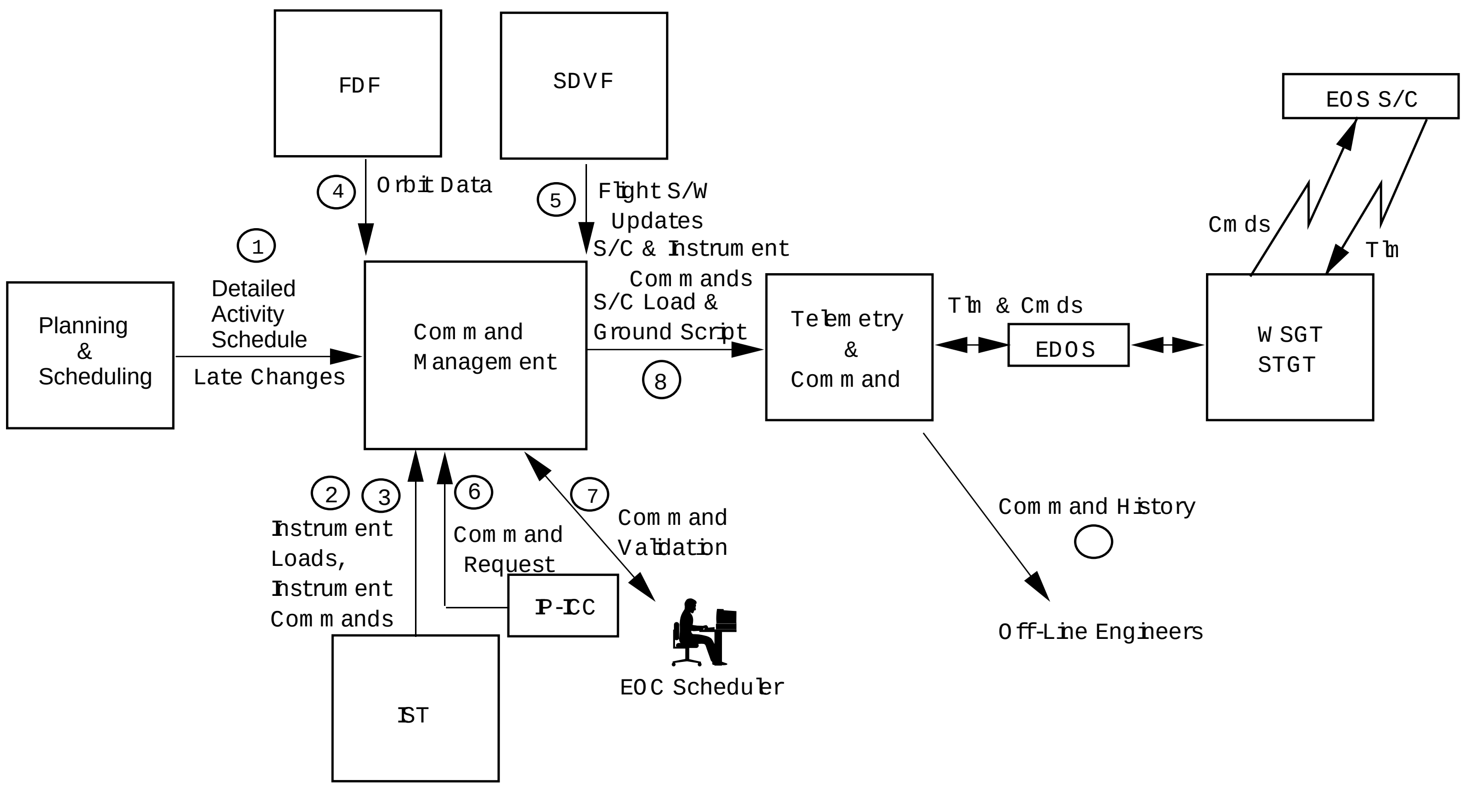

Figure 3.2.1-3. Command Load Generation Scenario

7. The EOC Scheduler validates the command data received from any IST. Validation includes an authorization check, command criticality checks, and schedule consistency.

   The EOC Scheduler performs constraint checking on all uplink data to ensure that there are no violations of spacecraft constraints.

8. The Command Management Service creates spacecraft loads and corresponding ground scripts for use by real-time operations. The ground script contains the ground directives necessary to uplink the spacecraft loads for each spacecraft, dump the spacecraft recorder, and process real-time housekeeping data.

9. The Off-Line Engineers review the command history in order to assess the command results.

3.2.2 Real-Time Scenario

This section describes a scenario that exemplifies nominal real-time operations in a multiple spacecraft environment. Inputs to this scenario include ground scripts and spacecraft and instrument loads that are produced by the Command Management service. Loads for each spacecraft and its instruments are available at the EOC for uplink approximately 24 hours in advance. The EOC ground scripts include steps to: uplink the loads; to dump the spacecraft recorders; and ground directives. Figure 3.2.2-1, FOS Real-Time Operations for U.S. EOS Spacecraft depicts the scenario described below.

The Operations Controller leads the shift operations for all spacecraft. Responsibilities include: briefings and debriefings; monitoring the activity timeline; coordinating institutional interfaces (i.e. NCC, FDF, EDOS); coordinating real-time scheduling changes; approving real-time commanding; and anomaly resolution.

Concurrent operations of multiple spacecraft are handled by multiple Command Activity Controller/Spacecraft Evaluator and Instrument Evaluator teams. Each team performs steps 1 through 7 in the subsequent scenario to provide the real-time operations for their designated spacecraft and instruments. The EOC provides each spacecraft simultaneous Telemetry and Command services. A given team need not be dedicated to a single spacecraft, but can instead support any given spacecraft for a period of time (e.g. a contact or a shift).

During real-time operations, the EOC ingests and processes spacecraft housekeeping telemetry, instrument housekeeping telemetry, and instrument engineering telemetry. Engineering telemetry data in a broad sense refers to the telemetered data available relating to the health, safety, environment, or status of the spacecraft and instruments. The spacecraft housekeeping telemetry refers to the subset of telemetered engineering data required for performing spacecraft operations. Similarly, the instrument housekeeping telemetry refers to the subset of telemetered engineering data required for performing instrument operations. Finally, the instrument engineering telemetry refers to the subset of telemetered engineering data required for performing instrument operations and science processing.

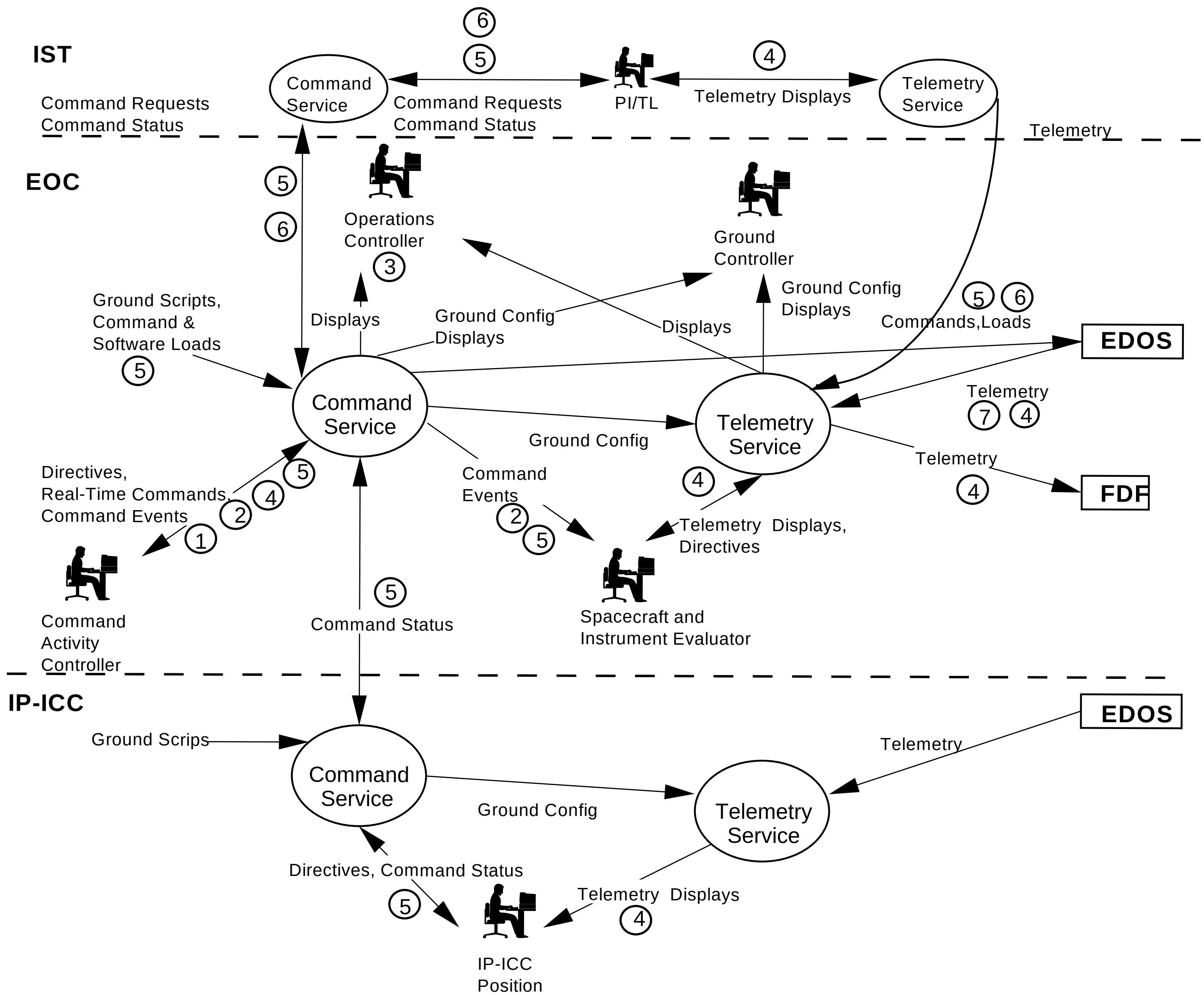

Figure 3.2.2-1. Real-Time Operations for U.S. EOS Spacecraft

For each type of telemetry, the EOC ingests both real-time and spacecraft recorded data. Real-time data refers to data that is acquired and transmitted immediately to the ground. Delays in real-time data are limited to the actual time of transmission. Spacecraft recorded data refers to data that has been stored on-board the spacecraft for delayed transmission to the ground.

3.2.2.1 Pre-Contact

1. The Command Activity Controller (for a given spacecraft and its instruments) issues a directive that initiates the EOC ground script for that spacecraft and the current day. The EOC ground script consists of time stamped directives for the EOC to process the current day's contact periods. The Command service performs an authorization check prior to activating the ground script. The ground script for a given spacecraft may only be initiated by the Command Activity Controller with command authority for that spacecraft (i.e. there is a single-point of command per spacecraft).
2. Once authorization is verified, the ground script is activated. The EOC executes the directives in the EOC ground script as indicated by the time stamp associated with each directive. The EOC ground script execution for a given spacecraft and its instruments is controlled by the Command Activity Controller and monitored by the S/C Evaluator. The EOC executes ground scripts for multiple spacecraft concurrently and independently.
3. Prior to the scheduled contact for a designated spacecraft, the EOC ground script for that spacecraft performs the necessary setup to ingest and process the real-time spacecraft and instrument housekeeping telemetry. This setup may include changes to limit sets, and ground equipment checkout. The Operations Controller is responsible for verifying the pre-contact ground configuration.

3.2.2.2 Contact

4. At a scheduled contact for a given spacecraft, the EOC automatically ingests and processes the real-time spacecraft and instrument housekeeping telemetry and instrument engineering telemetry. Subsets of the processed housekeeping telemetry may be forwarded to the FDF. The EOC ingests and processes real-time telemetry for multiple spacecraft and their instruments concurrently and independently.

   The Spacecraft Evaluator for a given spacecraft monitors telemetry displays providing information on the health and safety of that spacecraft and its subsystems. The Spacecraft Evaluator is notified of critical events such as missing data, bad quality, and limits violations.

   The Instrument Evaluator at the EOC and the PI/TL at the IST monitors telemetry displays providing information on the health and safety of the instruments. The Instrument Evaluator is notified of critical events such as missing data, bad quality, and limits violations.
5. During the contact for a given spacecraft, loads may be uplinked to that spacecraft either via the automated ground script or via a real-time directive entered by the Command Activity Controller. Prior to a load being uplinked via the real-time directive an authorization check is performed by the Command service. The Command service uplinks

the load via EDOS and performs command verification. The EOC uplinks loads for multiple spacecraft concurrently and independently.

The Spacecraft Evaluator and Command Activity Controller for a given spacecraft are notified of the uplink status and verify the execution of spacecraft commands.

The Instrument Evaluator at the EOC and the PI/TL at the IST are notified of the uplink status and the verification status of instrument commands. For AM-1, the loads are verified by examining a Cyclic Redundancy Check (CRC) status, which is included in the housekeeping telemetry. Real-time commands are verified by examining the command verification status in the housekeeping telemetry.

6. Real-time commanding may be initiated by the Command Activity Controller via a directive or the ground script. The Command service performs the authorization check, validates the command, and uplinks the command via EDOS. The EOC uplinks real-time commands to multiple spacecraft concurrently and independently.

   The Instrument Evaluator at the EOC and the PI/TL at the ISTs may request that a real-time command be uplinked during the contact. The Command Activity Controller may grant or deny this real-time command request. (Note: All command input from an IST, exclusive of instrument micro-processor loads, are in mnemonic form. Depending on the criticality of the command, concurrence from the EOC Command Activity Controller may be required prior to uplink.)

3.2.2.3 Post-Contact

7. Following the contact for a given spacecraft, the ground script executes directives to enable the Telemetry service to ingest and process spacecraft recorded spacecraft and instrument housekeeping telemetry from EDOS. The spacecraft recorded telemetry is temporarily archived at the EOC for local use by the Spacecraft Analysis service and permanently archived at the at the SDPS. The Spacecraft Evaluator verifies the successful completion of this operation. The EOC ingests and processes spacecraft recorded telemetry from EDOS for multiple spacecraft concurrently and independently.

3.2.3 Spacecraft Analysis Scenario

The Spacecraft Analysis service provides the FOT Spacecraft Evaluators, Instrument Evaluators, and Off-Line Engineers a set of tools to analyze spacecraft and instrument anomalies and deviations from expected performance standards. In particular, the Off-Line Engineers routinely analyze housekeeping telemetry trend data on the spacecraft subsystems to identify performance fluctuation issues (e.g., battery performance). Specific tools aimed at evaluating the functions, resources, and performance of spacecraft subsystems (e.g., Propulsion subsystem) are also routinely exercised by the Spacecraft Evaluator and the Off-Line Engineer.

After identifying a problem and its corrective action, the Spacecraft Evaluator and/or Off-Line Engineer follows approved procedures. If the anomaly is not time critical, the Spacecraft Evaluator and Off-Line Engineer works with the Mission Planner/Scheduling Supervisor and Scheduler to ensure that the corrective action plan is incorporated into a detailed activity schedule. If the corrective action is time critical, the Spacecraft Evaluator and Off-Line Engineer works with the Command Activity Controller to ensure that the corrective action plan is incorporated into the next available real-time contact period. In both cases, the corresponding commands are ultimately built, uplinked to the spacecraft, and verified.

The Spacecraft Evaluator and Off-Line Engineer also are provided with the capability to analyze real-time spacecraft housekeeping telemetry, spacecraft recorder housekeeping telemetry, and previously archived housekeeping telemetry. The selection of the telemetry to be analyzed, the time period over which the analysis is to occur, and the type of analysis to be performed (e.g., plot parameter(s) vs. time) are defined by the Spacecraft Evaluator and Off-Line Engineer.

Another function available to the Spacecraft Evaluator and Off-Line Engineers is to compare the Spacecraft Controls Computer (SCC) memory against the master ground image of the SCC memory. Nominally, the spacecraft loads are verified via the CRC check by the Command Activity Controller. However, in the case of an anomaly, the Spacecraft Evaluator and Off-Line Engineer can compare the SCC memory against the master ground image of the SCC memory.

The following scenario, depicted in Figure 3.2.3-1, demonstrates, in principal, how a Off-Line Engineer would detect, report, and resolve a spacecraft Power subsystem anomaly.

1. The Spacecraft Evaluator monitors the real-time housekeeping data for the Power subsystem. While monitoring the data, a yellow (warning) limit violation occurs that specifies that a threshold value has been crossed.
2. The Spacecraft Evaluator invokes a tool to provide in-depth analysis of the Power subsystem. This tool compares current values versus expected values, as well as analyzing trending data associated with the Power subsystem.

   The data analyzed in this scenario is real-time data, archived back-orbit housekeeping telemetry, and trend data. The Spacecraft Evaluator specifies the set of Power subsystem telemetry parameters to analyze. The Spacecraft Evaluator compares the results of a report of current value versus expected value. The plot indicates how a value has slowly degraded in the past several weeks.
3. From the results of the analysis, the Spacecraft Evaluator and Off-Line Engineer identify a corrective action plan that should be pursued. They follow pre-approved procedures to get the corrective action plan approved.
4. If the corrective action plan is not time critical, the Off-Line Engineer consults with the Scheduler to identify when the approved corrective activity can be incorporated into a detailed activity schedule.

   The Scheduler adds the activity to the applicable detailed activity schedule.

   The Off-Line Engineer reviews this schedule, and gives his approval.
5. If the corrective action plan is time critical, the Off-Line Engineer consults with the Command Activity Controller to identify when the approved corrective activity can be incorporated into a real-time contact.

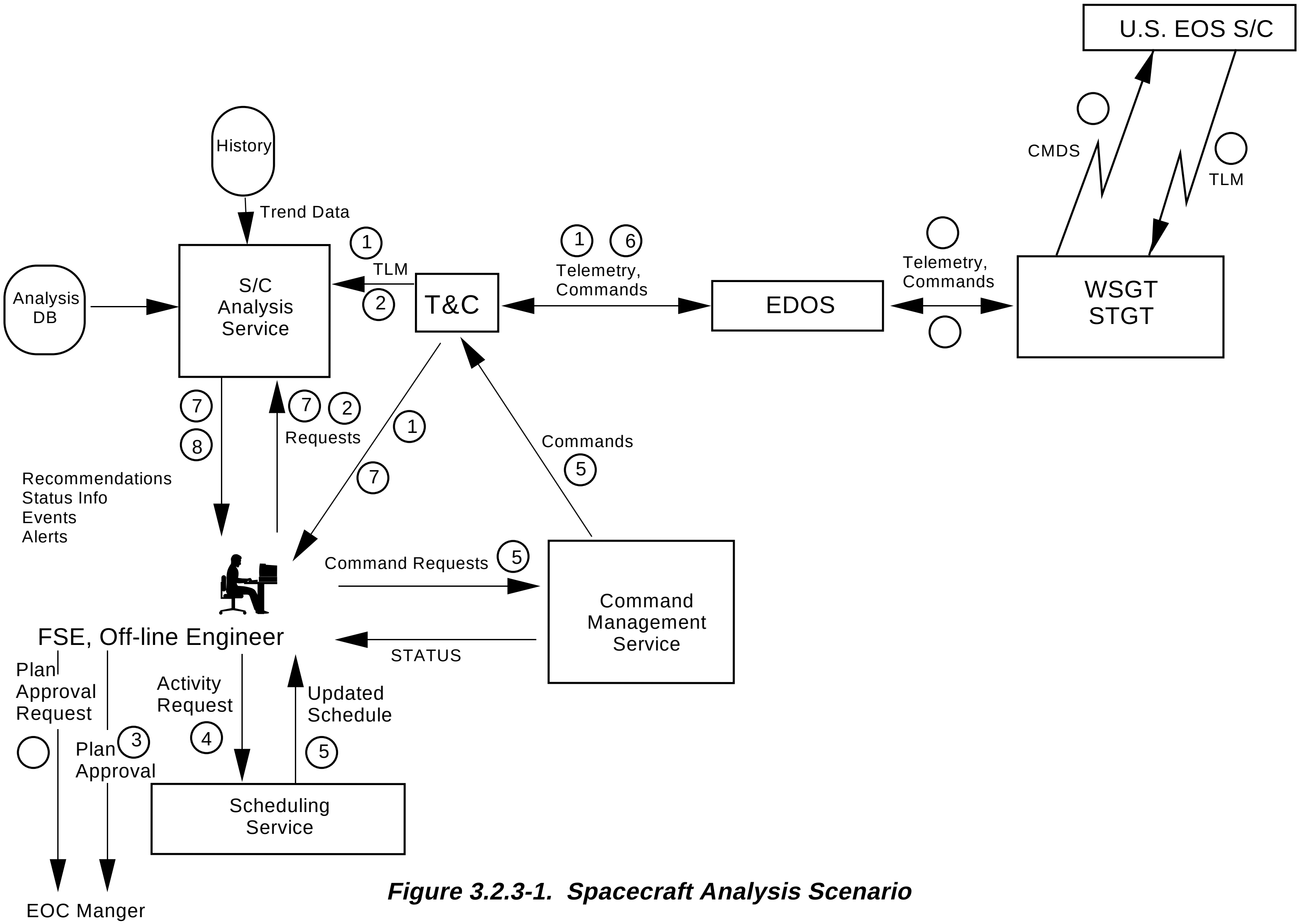

Figure 3.2.3-1. Spacecraft Analysis Scenario

6. The associated commands are uplinked to the spacecraft and verified. Subsequently, the corrective action commands are executed on-board the spacecraft.
7. The Spacecraft Evaluator reviews the real-time telemetry parameter(s) associated with the Power subsystem degradation anomaly, and confirms that the parameter(s) is now within the yellow limits range.
8. The Spacecraft Evaluator plots the expected resource value versus the actual value to re-confirm that the corrective action has been successful. Final validation is confirmed by the Off-Line Engineer in conjunction with the spacecraft Evaluator.